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EROSIVITY OF LOVA PROPELLANTS

J. R. Ward
T. L. Brosseau
R. P. Kaste
I. C. Stobie
B. Bensinger

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The erosivity of a series of LOVA propellants was evaluated with the BRL 37-mm blowout gun and with heat input measured in a 105-mm M68 tank cannon.

The results in the 37-mm blowout gun suggested that three of the eight propellants were as erosive as M30. Subsequent review of the closed bomb data used to calculate charge weights indicated that it is likely the extraordinary erosivity of these three propellants was caused by overestimating the propellant needed to match peak pressure of M30.

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Heat input measurements in the 105-mm tank gun showed that the six LOVA propellants tested were all less erosive than M30. The least erosive propellant was a mixture of RDX with a KRATON binder. Two propellants (80% RDX-PU and 80% HMX-CTBN) had heat inputs greater than the M735 projectile with a T_iO_2-wax liner. If either of these two propellants are selected for further evaluation, a wear-reducing liner should be considered. The remaining propellants gave sufficiently low heat inputs that an additive is probably not needed.

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I. INTRODUCTION

Gun propellants made with RDX or HMX, denoted nitramine propellants, have been labeled "inherently more erosive" than conventional propellants with equivalent flame temperatures.[1] This assertion has been rechecked the past few years using nitramine, double-base, and triple-base propellants with equivalent flame temperatures[2,3]. The different laboratory devices failed to give the same relative ranking in propellant erosivity. For this reason, it was deemed prudent to screen the erosivity of low-vulnerability (LOVA) propellants which have 75 or 80 percent by weight HMX or RDX along with suitable, usually inert, binders.[4-7] It was also hoped that the LOVA erosivity experiments would shed some light on the nitramine propellant erosivity controversy, since the LOVA propellants will be tested in a tank gun as well as the blowout gun used in reference 3.

II. EXPERIMENTAL

Tables 1 and 2 list the thermochemical properties and the chemical constituents of the LOVA propellant gases computed with the BLAKE thermochemical code,[8] along with M30 and M1 propellant gases for comparison. Those interested in the complete propellant formulations, choice of binders, and interior ballistic properties of the LOVA propellants should consult a series of reports from

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[1] *N.H. Smith, "Comparison of the Erosiveness of Propellant Powders," NDRC Armor and Ordnance Report A-451, October, 1945.*

[2] *A.J. Bracuti, L. Bottei, J.A. Lannon, and L.H. Caveny, "Evaluation of Propellant Erosivity with Vented Erosion Apparatus," Proceedings of the 1980 JANNAF Propulsion Meeting, CPIA Publication 315, March 1980.*

[3] *J.R. Ward, R.W. Geene, A. Niiler, A. Rye, and B.B. Grollman, "Blowout Gun Erosivity Experiments with Double-Base, Triple-Base and Nitramine Propellants," Proceedings of the 1980 JANNAF Propulsion Meeting, CPIA Publication 315, March 1980.*

[4] *J.J. Rocchio, H.J. Reeves, and I.W. May, "The Low-Vulnerability Concept-Initial Feasibility Studies," Ballistic Research Laboratory Memorandum Report 2520, August 1975.* (AD #B006854L)

[5] *J.J. Rocchio, H.J. Reeves, and I.W. May, "Low Vulnerability Ammunition Concept Development," Proceedings of the 1976 JANNAF Propulsion Meeting, CPIA Publication 280, February 1977.*

[6] *J.J. Rocchio and R.W. Deas, "Interior Ballistics of Nitramine Inert Binder Formulations being Evaluated for Low-Vulnerability Propellants," Proceedings of the 15th JANNAF Combustion Meeting, CPIA Publication No. 297, February 1979.*

[7] *W.H. Vreatt and S.E. Mitchell, "Navy LOVA Propellant Development," Proceedings of the 16th JANNAF Combustion Meeting, CPIA Publication 308, December 1979.*

[8] *E. Freedman, "BLAKE-A Ballistic Thermodynamic Code Based on TIGER," Proceedings of the International Symposium on Gun Propellants, Picatinny Arsenal, Dover, NJ, October 1973.*

TABLE 1. THERMOCHEMICAL PROPERTIES OF LOVA PROPELLANT COMBUSTION GASES

Propellant	Binder	Oxidizer	Pct	Flame Temp, K	Impetus J/g	Co-Volume cm^3/g	Specific Heat, J/mole-K	Mol Wt, g/mole	Ratio of Spec Heats
M30	--	--		3016	1078	1.05	44.0	23.2	1.24
M1	--	--		2446	919	1.11	40.9	22.1	1.27
L-1	PU*	HMX	75	2170	926	1.27	39.7	19.5	1.28
L-2	PU*	HMX	80	2438	1038	1.23	39.2	19.5	1.28
L-3	CA**	RDX	75	2549	999	1.15	40.3	21.2	1.27
L-4	CAB***	RDX	75	2500	1018	1.18	39.7	20.4	1.27
L-5	EC/NC****	RDX	73	2536	1056	1.21	39.3	20.0	1.28
L-6	CTBN*****	RDX	79	2379	1000	1.28	40.1	19.6	1.27
L-7	KRATON	RDX	80	2283	971	1.30	42.2	19.5	1.25
L-8	CTBN*****	HMX	80	2370	997	1.27	40.4	19.7	1.27

*Polyurethane
**Cellulose acetate
***Cellulose acetate butyrate
****Ethylcellulose/Nitrocellulose
*****Carboxyterminated butadiene acrylonitrite

TABLE 2. PRINCIPAL COMPONENTS OF COMBUSTION GASES FROM LOVA PROPELLANTS (Moles/Kg)

Propellant	CO	CO_2	H_2	H_2O	N_2
M30	11.9	2.9	5.6	10.4	11.9
M1	22.9	2.4	9.3	6.0	4.4
L-1	20.5	0.6	15.4	2.4	10.4
L-2	19.6	0.7	15.5	3.7	11.0
L-3	18.4	1.5	11.1	5.7	10.1
L-4	19.4	1.1	13.2	4.8	10.0
L-5	20.3	0.8	14.5	3.8	10.1
L-6*	21.0	0.2	15.2	0.9	10.5
L-7**	20.0	0.2	16.4	1.1	10.5
L-8***	21.3	0.2	14.9	0.7	10.5

*Propellant also produces 2.2 moles/kg of CH_4 and 0.8 moles/kg of HCN.
**Propellant also produces 2.8 moles/kg of CH_4 and 0.5 moles/kg of HCN.
***Propellant also produces 2.0 moles/kg of CH_4 and 0.7 moles/kg of C_2H_2.

the 1981 JANNAF Propulsion Meeting.[9-14] The abbreviations of the main binder ingredient are also listed in Table 1 to key propellants in this report with other reports on LOVA propellants.

From Table 1 one sees the LOVA propellants all have flame temperatures less than the M30 (3,000K) against which the LOVA propellants are being evaluated. The LOVA propellants produce gases with lower molecular weights and higher co-volumes than M30; Table 2 reveals the lower molecular weight comes from larger amounts of carbon monoxide and hydrogen relative to the standard propellants.

LOVA propellant erosivity was measured in the BRL 37 mm blowout gun and with heat inputs measured in an M68 tank cannon during the interior ballistic evaluation of the LOVA propellants. Details regarding the experimental apparatus and data analysis have been reported elsewhere.[7,15,16]

The thermocouples in the M68 tank cannon (SN 11200) were welded at the following distances from the bore surface:

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[9] *J.A. Kudzal, D.H. Brooks, and S.E. Mitchell, "Safety and Vulnerability Evaluation of LOVA Gun Propellants," to be published in the Proceedings of the JANNAF Propulsion Meeting, May 1981.*

[10] *R.W. Deas, "The Interior Ballistics Performance of Low-Vulnerability Ammunition (LOVA)," ibid.*

[11] *H.A. Dodohara, D. LaFleur and L.M. Torreyson, "Processing and Scale-up of LOVA Gun Propellant Candidates," ibid.*

[12] *C. Johnson, A. Dunay, and L. Torreyson, "KRATON-A New Thermoplastic Binder for LOVA," ibid.*

[13] *J.J. Rocchio, "The Low-Vulnerability Ammunition (LOVA) Program: A Progress Report," ibid.*

[14] *J.R. Cook, "Ignition Characterization of LOVA Propellant Using IR Laser," ibid.*

[15] *I.C. Stobie, T.L. Brosseau, and R.P. Kaste, "Heat Transfer Measurements in 105-mm Tank Gun with M735 Rounds" Ballistic Research Laboratory Technical Report-02265, September 1980.* (AD #A092351)

[16] *T.L. Brosseau, "An Experimental Method of Accurately Determining the Temperature Distribution and Heat Transferred in Gun Barrels," Ballistic Research Laboratory Report 1740, September 1974.* (AD #B000171L)

Thermocouple	Distance from Bore Surface, mm
TC-1	0.95
TC-2	1.35
TC-3	1.55
TC-4	2.59

III. RESULTS AND DISCUSSION

A. Blowout Gun

LOVA propellants L-1, L-2, L-8, and M30 were tested initially with a 12.4-mm diameter nozzle. Charge mass for each propellant was adjusted based on BLAKE code data to give a peak pressure of 306 MPa in order to insure that the 250-MPa rupture pressure of two 1.6-mm steel shear disks was exceeded. This mimicked the procedure for adjusting charge weights in the latest nitramine propellant erosivity experiments.[17] Propellant L-1 failed to rupture the shear disks prompting a check on any experimental closed bomb data. Some BRL experiments showed that M30 and L-2 had experimental peak pressures within four percent of theoretical, but L-1 was much lower. Charge weights of all LOVA propellants were adjusted using closed bomb data from either BRL or the Naval Ordnance Station (NOS) to match the experimental peak pressure of M30. Table 3 lists the final charge weights and the correction factors required.

Table 4 summarizes the mass losses with the 12.4-mm diameter nozzle. All three LOVA propellants are less erosive than M30 while L-1 seems significantly less erosive than L-2 or L-8 as befits the low flame temperature of L-1. The small mass loss per shot coupled with the scatter in the wear measurements caused concern that it would not be possible to distinguish erosivity among all the LOVA propellants, so a 6.4-mm diameter nozzle was substituted for the rest of the tests. The only reason to stay with the 12.4-mm diameter nozzle would have been to compare the LOVA propellants with the other nitramine propellants in reference 17, but the M30 erosivity in these tests was one-half that of the M30 in smaller web reference 17 meaning the LOVA propellants and smaller-web propellants in reference 17 could not be compared directly. The nominal rupture pressure was kept at 250 MPa by removing one shear disk, so charge weights were unchanged.

Table 5 contains the wear data from the 6.4-mm diameter nozzle; Table 6 summarizes the mean mass losses, thermochemical properties, and correction factors.

Propellant L-7 did not rupture the shear disk even with the correction factor, so the charge weight was increased another five percent. One also notes that propellants L-3, L-4, and L-5 wore as much as M30 despite the nominally lower flame temperatures. These discrepancies prompted a closer look at the closed bomb data. One lot was found which had been tested at both BRL and NOS. The results are compared below:

[17] *R.P. Kaste, I.C. Stobie, J.R. Ward, and B.D. Bensinger, "Nitramine Propellant Erosivity," to be published in the Proceedings of the 1981 JANNAF Propulsion Meeting, May 1981.*

TABLE 3. CHARGE MASSES AND CORRECTION FACTORS OF LOVA PROPELLANTS FIRED IN THE 37-mm BLOWOUT GUN

Propellant	Oxidizer	Charge Mass, g	Correction Factor*
M30	---	72.2	-
L-1	HMX	84.7	1.10
L-2	HMX	71.5	1.00
L-3	RDX	75.7	1.01
L-4	RDX	77.6	1.06
L-5	RDX	80.4	1.13
L-6	RDX	64.8	0.97
L-7	RDX	76.6	1.04
L-8	HMX	75.3	1.04

**Ratio of propellant needed from closed bomb data to match P_{max} of M30 to that calculated by thermochemical codes to match P_{max} of M30.*

TABLE 4. MASS LOSSES FOR FIRINGS THROUGH 12.4-mm DIAMETER NOZZLE

Shot No.	Mass Loss, mg			
	M30	L-1	L-2	L-8
1	4.6	0.5	1.7	0.6
2	3.0	0.4	1.3	1.9
3	4.7	0.8	1.3	1.1
4	2.3	0.3	1.1	1.2
5	5.3	0.6	1.4	2.6
6	3.7		1.0	2.0
7				1.2
8				1.9
Flame Temp, K	3016	2170	2438	2370
Charge Mass, g	72.2	84.7	71.5	75.3
Mean Mass Loss,mg/shot	3.9	0.52	1.3	1.6
Sample Standard Deviation, mg/shot	1.1	0.2	0.2	0.6

TABLE 5. WEAR MEASURED WITH 6.4-mm DIAMETER NOZZLES

Shot No.	Mass Loss, mg/shot								
	M30	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8
1	64.8	1.9	36.6	95.2	80.2	86.1	12.4	8.8	18.8
2	72.7	2.1	6.4	66.3	48.1	76.1	21.0	13.3	18.1
3	69.2	0.7	11.9	57.1	42.9	97.2	29.9	9.2	19.6
4	74.2	0.9	20.7	66.2	72.7	76.9	31.3	2.4	
5	57.8	1.4	24.9	62.3	54.4	73.1	27.2	8.5	
6			25.5		30.4	94.3	27.3	8.0	
7					30.1				
Mean mg/shot	67.7	1.4	21.0	69.4	51.3	90.0	24.8	8.4	18.8
Sample Standard Deviation,mg/shot	6.6	0.6	10.7	14.9	19.4	10.2	7.0	3.5	0.8

TABLE 6. SUMMARY OF WEAR MEASUREMENTS FOR LOVA PROPELLANTS

Propellant	Flame Temp, K	Impetus J/g	Co-Volume, cm^3/g	Charge Mass, g	Correction Factor	Mass Loss, mg/shot	Oxidizer	Binder
M30	3,016	1,078	1.05	72.2	1.00	67.7 ± 6.6		
L-1	2,170	926	1.27	84.7	1.10	1.4 ± 0.6	HMX (75)	PU
L-2	2,438	1,038	1.23	71.5	1.00	21.0 ± 10.7	HMX (80)	PU
L-3	2,549	999	1.15	75.7	1.01	69.4 ± 14.9	RDX (75)	CA
L-4	2,500	1,018	1.18	77.6	1.06	51.3 ± 19.4	RDX (75)	CAB
L-5	2,536	1,056	1.21	80.4	1.13	90.0 ± 10.2	RDX (73)	EC/NC
L-6	2,379	1,000	1.28	64.8	0.97	24.8 ± 7.0	RDX (79)	CTBN
L-7	2,283	971	1.30	80.4	*	8.4 ± 3.5	RDX (80)	KRAYTON
L-8	2,370	997	1.27	75.3	1.04	18.8 ± 0.8	HMX (80)	CTBN

**Propellant mass from closed bomb data needed to match M30 failed to rupture shear disk; extra five percent more propellant added to insure disk rupture.*

	BRL	NOS
Closed bomb volume, cm^3	197.8	185.2
Propellant mass, g	52.8	47.17
Loading density, g/cm^3	0.267	0.255
Expt'l peak pressure, MPa	371	322
Theo. peak pressure, MPa	408	366
Ratio, theo/expt'l	1.08	1.14

The theoretical/experimental ratio for M30 was taken from BRL results, so correction factors based on the NOS results would overestimate the propellant needed to match M30. Correction factors for L-3, L-4, and L-5 were based on NOS results.

Table 6 shows that propellants L-1, L-2, L-6, L-7, and L-8 are less erosive than M30. Since it is likely any error in matching peak pressures to M30 tend to increase erosivity, the vented bomb results suggest these LOVA propellants are less erosive than M30.

B. Heat Input Measurements

The interior ballistics phase of the LOVA program consisted of firing different charge weights of each LOVA candidate at ambient temperature[10]. A charge weight was then selected which matched M30 P_{max} as closely as possible. Replicate firings were made at ambient temperature, 243K and 333K. Heat input measurements were made with the rounds fired at ambient, since total heat input has been correlated with wear only at ambient temperatures.[18] Firings were done with six of the eight LOVA propellants tested in the blowout gun. Not enough L-1 and L-6 was available for the interior ballistics phase.

Individual temperature measurements are listed in Tables 7 and 8 along with pertinent interior ballistics to show how closely the LOVA propellants match M30. The thermocouple nearest the bore surface broke during testing presumably because gun wear moved the thermocouple junction too close to the surface to withstand the pressure pulse. Table 9 lists the stargauge readings at the axial distance where the thermocouples are located over grooves. The M68 cannon is condemned when the vertical land wear reaches 1.42 mm.[19] In order to compute heat input for rounds in the worn tube, the thermocouple distances to the bore surface were reduced 0.36 mm, the average radial groove wear. An M30 round was fired on 17 October as a control.

Tables 10 and 11 collect the mean temperature readings used to compute the total heat inputs. The total heat inputs are collected in Table 12 where one sees the LOVA propellants are all less erosive than M30 including the three propellants (L-3, L-4, and L-5) which seemed as erosive as M30 in the blowout

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[18] *T.L. Brosseau and J.R. Ward, "Measurement of Heat Input into the M68 Cannon with Wear-Reducing Additives," Ballistic Research Laboratory Technical Report ARBRL-TR-02056, April 1978. (AD #A056368)*

[19] *"Evaluation of Cannon Tubes," DA Technical Manual TM 9-1000-202-14, November 1976.*

TABLE 7. M30 THERMOCOUPLE MEASUREMENTS

	Temp, K	Temp. Rise, K, 100 ms after ignition				Prop. Mass, kg	Proj. Mass, kg	Chamber Pressure, MPa	Muzzle Vel,m/s
		TC-1	TC-2	TC-3	TC-4				
9May	293	171	117	98	37	5.62	5.78	419	1508
12May	294	174	117	98	37	5.62	5.77	--	1504
12May	294	170	117	100	38	5.62	5.78	418	1506
13May	293	177	117	99	35	5.62	5.78	--	1504
13May	293	177	117	99	37	5.62	5.78	429	1502
19May	293	175	119	106	37	5.62	5.77	439	1510
19May	294	172	120	99	35	5.62	5.78	435	--
25Jun	298	171	116	104	38	5.62	5.78	427	--
17Oct	291	*	142	134	55	5.62	5.78	395	1498

* *Not available.*

TABLE 8. LOVA PROPELLANT THERMOCOUPLE MEASUREMENTS

Date	Prop.	Temp,K	Temp. Rise, K, 100 ms after ignition				Prop. Mass, kg	Proj. Mass, kg	Chamber Pressure, MPa	Muzzle Vel,m/s
			TC-1	TC-2	TC-3	TC-4				
1980 26Jun	L-2	298	160	111	97	37	5.53	5.78	426	1479
22Oct	L-3	294	*	120	113	49	4.98	5.79	426	1428
22Oct	L-3	294	*	122	114	52	4.98	5.78	429	1424
22Oct	L-3	294	*	129	121	46	4.98	5.78	419	1424
17Oct	L-4	295	*	123	116	48	5.94	5.78	431	1492
17Oct	L-4	295	*	123	117	47	5.94	5.80	426	1488
17Oct	L-4	295	*	128	122	49	5.94	5.78	406	1474
23Oct	L-5	295	*	111	97	45	5.58	5.78	431	1492
23Oct	L-5	295	*	102	82	41	5.58	5.78	432	1496
23Oct	L-5	295	*	108	76	35	5.58	5.78	422	1490
1981 28Jan	L-7	290	*	75	64	27	5.75	5.78	410	1424
28Jan	L-7	290	*	80	67	27	5.75	5.78	419	1428
1980 22Jul	L-8	298	161	111	106	39	6.03	5.77	414	1472
23Jul	L-8	302	155	104	94	39	6.03	5.78	417	1468

Not available.

TABLE 9. STARGAUGE MEASUREMENTS AT 641.4-mm FROM REAR FACE OF M68 CANNON SN 11200

Date	Rounds Fired	Wear, mm			
		Vert.Land	Horiz.Land	Vert.Groove	Horiz.Groove
15 May 80	17	0.15	0.10	0.05	0.08
7 Nov 80	101	1.35	1.40	0.69	0.76

TABLE 10. SUMMARY OF THERMOCOUPLE MEASUREMENTS-NEW TUBE

Prop.	No. Shots	Temp. Rise, K, 100 ms after ignition				Prop. Mass, kg	Proj. Mass, kg	Chamber Pressure, MPa	Muzzle Vel,m/s
		TC-1	TC-2	TC-3	TC-4				
M30	8	173	118	100	37	5.62	5.78	428	1506
L-2	1	160	111	97	37	5.53	5.78	418	1475
L-8	2	158	108	100	39	6.03	5.78	417	1468

TABLE 11. SUMMARY OF THERMOCOUPLE MEASUREMENTS-WORN TUBE

Prop.	No. Shots	Temp. Rise, K, 100 ms after ignition			Prop. Mass, kg	Proj. Mass, kg	Chamber Pressure, MPa	Muzzle Vel, m/s
		TC-2	TC-3	TC-4				
M30	1	142	134	55	5.62	5.78	395	1498
L-3	3	124	116	49	4.98	5.78	425	1425
L-4	3	125	118	48	5.94	5.78	421	1485
L-5	3	107	85	40	5.58	5.78	428	1493
L-7	2	87	66	27	5.75	5.78	415	1426

TABLE 12. SUMMARY OF HEAT INPUT MEASUREMENTS

Prop.	Oxidizer	Binder	Flame Temp, K	Q, J/mm	Prop. Mass, kg	Chamber Pressure, MPa	Muzzle vel, m/s
M30	--	--	3016	443	5.62	428	1506
L-2	HMX (80)	PU	2438	413	5.53	418	1475
L-8	HMX (80)	CTBN	2370	406	6.03	417	1468
L-3	RDX (75)	CA	2549	358	4.98	425	1425
L-4	RDX (75)	CAB	2500	358	5.94	421	1485
L-5	RDX (73)	EC/NC	2536	301	5.58	428	1493
L-7	RDX (80)	KRATON	2283	236	5.75	415	1426

gun. On the basis of flame temperatures one might have expected propellants L-2 through L-5 and L-8 to have about the same erosivity, while L-7 would be less erosive than all other propellants tested. Instead the order appears to be M30 > L-2 ∿ L-8 > L-3 ∿ L-4 > L-5 > L-7. Before trying to rationalize these differences, one should insure that the thermochemical properties correspond to the calculated values.

In order to convert heat input to wear, one can use heat input results gathered for the M392A2 projectile with different additives (Table 13). Brosseau and Ward[18] showed the logarithm of wear was linearly dependent on heat input above a threshold of 370 J/mm. Table 14 shows the wear estimated for each LOVA propellant using the wear vs heat input correlation from the M392 projectiles. Two LOVA propellants, L-5 and L-7, fall below the threshold, so one can only say the wear would be less than the M392 projectile with its T_iO_2-wax liner. Table 14 implies that one should use an additive with propellants L-2 and L-8, especially in view of heat input for the M735 with additive which gives 405 J/mm with one shot.[15] One would predict that L-2 and L-8 without additive would be more erosive than the M735. Conversely, one would predict that the other LOVA propellants could be considered for use without any additive, particularly LOVA L-5 or L-7. Another advantage of using propellants without additive is that the secondary wear problem should disappear and the condemnation limit eventually returned to 1.90 mm. The introduction of LOVA propellant into the combat rounds brings wear from the combat rounds in line with the training rounds and eliminates the problem of finding worn-tubes to do lot acceptance tests on the M735, M774, and eventually, the XM833. Actual gun wear data for LOVA propellants will be produced when the LOVA propellant programs enters engineering development.

IV. CONCLUSIONS

1. Erosivity of LOVA propellants was tested in a 37-mm blowout gun and in a 105-mm M68 tank cannon equipped with thermocouples to measure total heat input. Heat input measurements in the M68 cannon show all the LOVA propellants are less erosive than M30 propellant. In the 37-mm blowout gun, three propellants appeared at least as erosive as M30. There is serious question, however, about the method used to determine charge weights for the blowout gun experiments that may have exaggerated LOVA propellant wear relative to M30.

2. Heat input measurements were converted to wear using a heat input-wear correlation for M392 projectiles. It appears that two LOVA propellants (80% RDX-PU and 80% HMX-CTBN) would require a wear-reducing additive to keep wear comparable to M735 and M774. The other LOVA propellants, particularly the propellants with KRATON or EC/NC binders, would produce little wear without any additive.

3. LOVA propellant with the KRATON binder gave the lowest heat input and would be the propellant of choice from the standpoint of minimizing gun wear.

TABLE 13. WEAR AND HEAT INPUT FOR M392 CARTRIDGES

Round	Additive	Heat Input, J/mm	Wear, μ/shot	Wear Life, Rounds*
M392	none	449	18	80
M392	polyurethane	416	4.1	350
M392	T_iO_2-wax	381	0.18	7900

Based on condemnation limit of 1.42-mm.

TABLE 14. ESTIMATED WEAR FOR LOVA PROPELLANTS

Propellant	Heat Input, J/mm	Wear, μ/shot	Wear Life, Rounds
L-2	413	3.5	400
L-8	405	2.5	570
L-3, L-4	358	0.3	4,800
L-5	301	< 0.2	> 8,000
L-7	236	< 0.2	> 8,000

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